The decrease in severity of asthma in children of parents who smoke since the parents have been exposing them to less cigarette smoke

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Background: *In 1985 we became aware that the smoking of parents aggravates their children's asthma. Since then we have advised all referring doctors to urge parents not to expose their asthmatic children to smoke.*
Methods: *We investigated 807 nonsmoking asthmatic children, from 1 through 17 years of age, who were consecutively referred between 1983 and 1990. We compared the children who were seen before July 1986 with those seen after that date.*
Results: *Those seen in the later period had intimate exposure to a far smaller number of cigarettes smoked per day, both by mothers (7 vs 3, p = 0.005) and by fathers (5 vs 2, p = 0.001). A concurrent improvement was observed in adjusted measures of asthma severity in their children (asthma score 7.5 vs 6.5, p = 0.047; forced expiratory volume in 1 second as a percent of predicted [FEV_1%] 79.2 vs 93.7, p = 0.000; and forced expiratory flow rate during middle half of forced vital capacity [$FEF_{25\%-75\%}$] 67.3 vs 82.0, p = 0.009), and for every cigarette less smoked in the room with the child the FEV_1 increased by 3%. When parents of those seen in the later period were asked whether they had been told that smoke would aggravate their child's asthma, 80% affirmed that they had. The difference in asthma severity between the two time periods was much less in children of nonsmokers than in children of smokers.*
Conclusions: [redacted]
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Key words: *Smoke pollution, asthma severity, children, counseling*

Surveys of asthmatic children performed before 1986 report more severe symptoms and lower lung function test results if the children are exposed to smoke in the home.[1-4] Both the medical profession and the general public have become aware that smoke aggravates asthma. This is particularly apparent in the province of British Columbia where articles on the subject have been published in the medical and in the lay press,[5,6] and where all doctors who refer patients to the allergy clinic at Children's Hospital in Vancouver have, since 1985, been urged to counsel parents of asthmatic children never to smoke when in the home.

Abbreviations used

FVC:	Forced vital capacity
FEV_1:	Forced expiratory volume at 1 second
FEV_1%:	Ratio of forced expiratory volume in 1 second to forced vital capacity
$FEF_{25\%-75\%}$:	Forced expiratory flow rate during the middle half of the forced vital capacity
PC_{20}:	Provocation concentration of aerosolized histamine necessary to cause a 20% fall in FEV_1

Since 1983 we have been gathering data on passive smoking and on asthma severity in children who have attended our clinic. From 1983 until 1986 we observed more severe asthma in children of smokers than in those of nonsmokers, but since 1986 there has been a marked lessening in the severity of asthma in children of smokers, their asthma being no more severe than that in children of nonsmokers. It appears likely that much of this improvement is the result of the parents' awareness of the harmful effects of smoke.

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and a consequent decrease in exposure of asthmatic children to smoke.

MATERIAL AND METHODS

The series included every child with asthma, 1 to 17 years of age, who had been referred to the allergy clinic at the Children's Hospital in Vancouver, British Columbia, between Nov. 1, 1983, and June 30, 1990 and had been seen by A.B.M., one of two pediatric allergists who conduct alternate sessions at the clinic. All patients, new and old, were included in the series. The history, physical findings, and special investigation results used in the study were those recorded at a single visit. The parents were contacted 2 weeks before the appointment and then again 48 hours before the appointment and were instructed as to which medications to withhold so that these would not decrease bronchial responsiveness to histamine and skin test reactions.

Questionnaire

A trained interviewer asked standardized questions of the accompanying adult. In 99% of cases this was a parent, and in 92% of cases it was the mother, either alone or accompanied by the father. Parents were asked how many days during the past year the child had wheezed and had taken medication, whether corticosteroids had been given, whether the child wheezed on exertion, and how severe they thought the child's asthma had been. Each of their answers was given a number according to severity, and the sum of these numbers was the asthma score (Appendix). In addition, they were asked about other features that might influence the severity of asthma, variables such as age of onset of asthma, number of respiratory infections, and the presence of animals in the house.

The last questions to the accompanying parents were about smoking. They were asked how many cigarettes each of them smoked per day, the total number and the number smoked when in the house.[7] From June 1985 to June 1986 they were also asked how many cigarettes they smoked when in the same room as the child. This question was discontinued at the end of June 1986 because parents hesitated considerably longer in answering this question than any other question, and because the correlation of asthma severity with this number of cigarettes was not significantly greater than with the number smoked when in the home. By 1988, however, it became obvious that parents were smoking fewer cigarettes when in the same room with their child than parents had done previously. Therefore this question was reintroduced to our standard questionnaire in January 1989.

Finally, the child was asked privately whether or not he or she smoked. The seven children who admitted to being smokers were excluded from the study. Also excluded were five who had cystic fibrosis and one who had marked gastroesophageal reflux.

Skin prick tests

By use of a standard method skin prick tests were performed with a negative (saline) and positive (histamine) control solution,[8] extracts of 1% *Dermatophagoides farinae* and *D. pteronyssinus* (Beneard Division of Beecham Laboratories, United Kingdom), and dog and cat hair (Hollister Stier, Spokane, Wash.). These and the other tests were performed by a technician who had no knowledge of the smoking habits of the family.

Forced expiratory spirogram

Children who were 6 years of age and older performed forced expiratory maneuvers until there were three recordings in which the forced vital capacity (FVC) agreed within 5%. This was achieved in five or fewer efforts by all except eight children. In these children who produced an acceptable spirogram, the tracing that had the greatest sum of FVC and forced expiratory volume at one second (FEV_1) was used for all measurements.[8] The FVC, FEV_1, and the forced expiratory flow rate during the middle half of the FVC ($FEF_{25\%-75\%}$) were expressed as a percentage of the predicted mean for age, sex, and height.[10]

The spirogram was recorded with Pulmanor, Datamite III and Datamite V spirometers (Jones Medical Instrument Co., Oak Brook, Ill.), all of which were calibrated weekly with a known volume of carbon dioxide discharged at a standard velocity from a Jones Calibrator. The results were analyzed and printed by Datamatic computers (Jones Medical Instrument Co.) that were connected to the spirometers.

Bronchial responsiveness to histamine

A bronchial challenge test was performed on the children who were 7 years of age and older, except for those who had taken bronchodilators or antihistamines so recently that there was a risk of the test results being affected, those who reported a cold or respiratory infection within the preceding 2 weeks, and those whose FEV, was less than 1 L in volume or was less than 60% of predicted value. One hundred seventy-eight subjects were tested. We used a modification of the protocol of Cockcroft et al.[9, 11] to give the patient's responsiveness to histamine acid phosphate aerosol generated by air flowing at 8 L/min through a Wright nebulizer (Aerosol Products Ltd., London, England). Doubling concentrations were administered by a loosely fitting mask until we reached the provocation concentration required to cause a 20% decrease in FEV, (PC_{20}). The strongest concentration administered was 8 mg/mL. Children whose FEV, did not decrease by 20% when this concentration was administered were eliminated from analyses of bronchial responsiveness. There were few such children. Two of the children had mothers who smoked, and 14 had mothers who did not smoke. Informed consent was obtained from the parents or guardians of the children who served as subjects for this investigation.

Expired air carbon monoxide concentration

To verify that subjects who claimed to be nonsmokers were being truthful, the carbon monoxide (CO) levels in expired air were measured on all children who were 9 years of age and older and were seen in 1988, 1989, and 1990. After 10 seconds of breathholding, the subject blew into a Vitalor CO monitor (Vitalograph Medical Instrumentation, Buckingham, England).[12] The monitor was calibrated weekly. None of those who claimed to be nonsmokers had a CO level higher than 8 ppm, whereas all who admitted to being smokers did.

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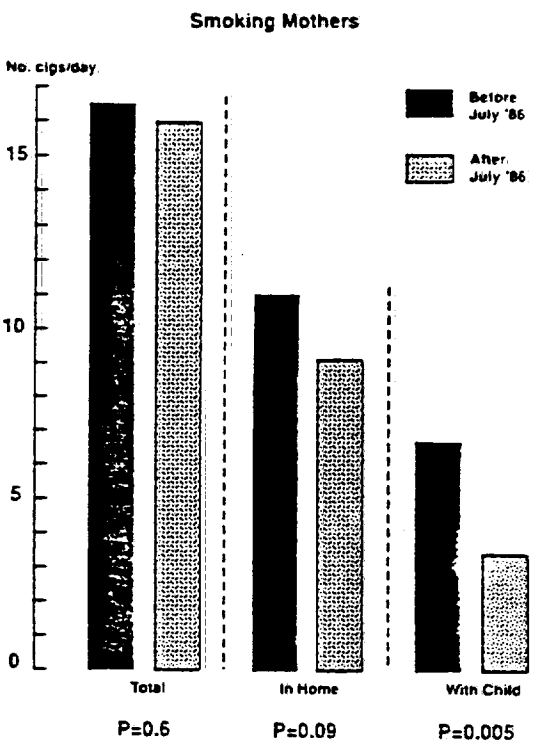

FIG. 1. Number of cigarettes smoked per day by mothers who smoked. Number smoked in total and when in the house was known for 204 of the 205 mothers, and number smoked when in the same room as the child known for all 93 children seen from June 1, 1985, through June 30, 1986, and from Jan. 1, 1989, through June 30, 1990.

Statistical analysis

After exclusion of the children who were themselves smokers, those with cystic fibrosis, and the one who had marked gastroesophageal reflux, 807 remained. Four hundred fifteen of these were seen before July 1986, and 392 were seen after July 1986. Henceforth these will be referred to as the earlier and the later groups.

In a preliminary analysis, Student *t* tests were used to test the difference between means, and Pearson product-moment correlation coefficients were calculated to measure the association between the measures of asthma severity and the logarithms of the number of cigarettes the mother or father smoked. For the main analysis, analysis of covariance (ANCOVA) was used. The model incorporated two factors, sex and time period (before or after July 1986) and two covariates, age and age of onset of asthma. Then, to account for smoking exposure, the logarithm of the number of cigarettes the mother smoked when in the same room as the child, and the logarithm of the number of cigarettes the father smoked when in the same room as the child, were included as covariates in one of the analyses of those children who had a parent who smoked. The number available for the main analysis was 570 because information on the number of cigarettes smoked when in the same room as the child had been sought only during the periods June 1985 through June 1986 and January 1989 through June 1990.

RESULTS

Two sets of analyses were performed. The first was a preliminary one to determine whether parents were smoking fewer cigarettes and whether there had been a concomitant lessening in the severity of the children's asthma. After this a second analysis was carried out to assess if the change in asthma severity could be explained by the change in the parents' smoking habits. This was done by integrating the smoking and asthma severity data in analyses of covariance.

Preliminary analysis

The preliminary set of analyses showed that although there was little change in the total number of cigarettes the parents smoked per day when comparing the earlier and later periods, 17 versus 16 by mothers ($p = 0.6$) and 20 versus 19 by fathers ($p = 0.3$), the mean number of cigarettes smoked when in the same room as the child decreased markedly, 7 versus 3 by mothers ($p = 0.005$) and 5 versus 2 by fathers ($p = 0.001$, Fig. 1, Table I). Concurrent with the lessened exposure to the mothers' smoke there was a marked improvement in the children's lung function (Fig. 2, Table II A). A similar but lesser improvement was observed in children whose fathers smoked (Table II B). Not only was there evidence of much better air flow in those seen in the later than in the earlier period, but a dose-response gradient was also present; the correlations representing this gradient are given in Table III. As well, significant correlations occurred between the number of cigarettes the mother smoked in the house and the child's asthma score ($p = 0.021$), $FEV_1\%$ ($p = 0.011$), and $FEF_{25-75\%}$ ($p = 0.046$), although not the logarithm of the PC_{20} ($p = 0.43$).

To determine whether a difference in some other parameter might be contributing to the apparent improvement that occurred in smokers' children, the means of other possibly relevant variables were compared for children seen in the two time periods. They were the following: age, sex, presence of allergic nasal symptoms, a history of atopic dermatitis, a family history of asthma, number of siblings, recent respiratory infection, number of colds per year, ownership of a dog by children with a positive skin test to dog, ownership of a cat by children with a positive skin test to cat, positive skin test to house dust mite, age of onset of asthma, wood stove used for heating the house, and a gas range used for cooking. The means

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TABLE I. Number of cigarettes smoked by parents of children seen before and after July 1986

Measurement	No. of cigarettes per day Mean and SE: Before July 1986 (no. subjects)	After July 1986 (no. subjects)	2-tail probability
Mother			
Total no.	16.6 ± 1.0 (92)	15.9 0.8 (113)	0.568
At home	11.0 ± 0.8 (80)	9.0 0.7 (113)	0.060
Same room with child	6.6 0.9 (40)	3.4 0.6 (53)	0.005
Father			
Total no.	20.2 ± 1.1 (118)	18.8 ± 0.9 (135)	0.329
At home	8.3 ± 0.6 (99)	6.1 ± 0.5 (133)	0.004
Same room with child	4.6 ± 0.6 (47)	2.0 ± 0.4 (64)	0.001

Numbers given are total number smoked per day, number smoked when in the house, and number smoked when in the same room as the child.

TABLE II A. Unadjusted means of indicators of asthma severity in 807 children seen before and after July 1986

Measurement	Before July 1986 Mean	SE	No. subjects	After July 1986 Mean	SE	No. subjects	2-tail probability
Mother smoker							
Asthma score	8.2	0.3	92	5.8	0.2	112	0.000
FEV,%	77.3	2.1	69	91.3	1.5	59	0.000
$FEF_{25-75\%}$	59.5	3.1	69	81.0	3.1	59	0.000
Log PC_{20}	− 0.23	0.27	26	0.41	0.27	24	0.098
Mother nonsmoker							
Asthma score	6.4	0.2	321	6.6	0.2	275	0.51
FEV,%	84.4	1.1	224	90.8	1.2	148	0.000
$FEF_{25-75\%}$	71.7	1.8	224	79.4	2.0	148	0.005
Log PC_{20}	0.44	0.14	66	0.26	0.21	46	0.450

Data for asthma score or mother's smoking status unavailable on seven subjects.

TABLE II B. Unadjusted means of indicators of asthma severity in 807 children seen before and after July 1986

Measurement	Before July 1986 Mean	SE	No. subjects	After July 1986 Mean	SE	No. subjects	2-tail probability
Father smoker							
Asthma score	7.1	0.3	118	6.5	0.2	134	0.065
FEV,%	80.2	2.0	84	93.0	1.7	64	0.000
$FEF_{25-75\%}$	67.1	3.0	84	84.1	2.8	64	0.000
Log PC_{20}	0.12	0.18	32	0.74	0.26	23	0.050
Father nonsmoker							
Asthma score	6.7	0.2	283	6.3	0.2	253	0.183
FEV,%	84.2	1.0	201	90.1	1.2	143	0.000
$FEF_{25-75\%}$	70.0	1.8	201	78.0	2.1	143	0.004
Log PC_{20}	0.32	0.17	60	0.10	0.20	47	0.403

Data for asthma score or father's smoking status unavailable on 19 subjects.

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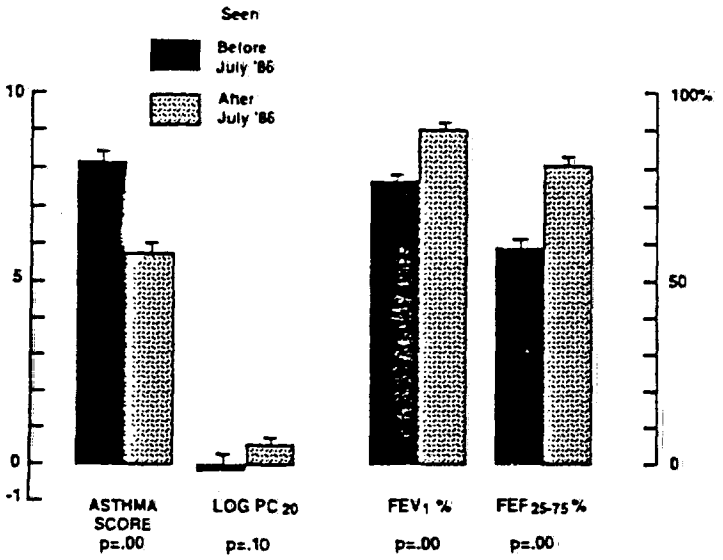

FIG. 2. Indicators of asthma severity in children of mothers who smoked.

were similar for all these variables except for age: those seen during the later period were, on average, 2 years younger than those seen during the earlier period ($p < 0.01$). The probable reason for this difference is that some of those seen in the earlier period were children whose first visit to the clinic had been before the start of the study, whereas those seen in the later period were all new patients.

Main analysis

Three analyses of covariance were carried out for each of the four measures of asthma severity. One was on children of nonsmokers, and the other two were on children of smokers. The overall purpose of the analyses was to determine changes in asthma score and in lung function test results after adjustment for variables found previously to affect asthma severity. These variables were sex, age, and age of onset of asthma.[13, 14] The model incorporated sex and time period as the factors and age and age of onset as covariates in the three analyses. In the second analysis on smokers' children we included the logarithm of the number of cigarettes the mother smoked when with the child and the logarithm of the number of cigarettes the father smoked when with the child. The results of the 12 analyses are given in Table IV. The first two columns indicate that smokers' children (column 2), compared with nonsmokers' children (column 1), had greater improvement in asthma score and in spirometric test results across the time period. The third column indicates that this difference across the time periods in smokers' children is decreased if the number of cigarettes smoked when with the child is taken into account, as would be expected if exposure to the parents' cigarette smoke is a reason for the difference.

No significant improvement in PC_{20} was seen across the time periods in either nonsmokers' or in smokers' children, but in the smokers' children the mean values of the log PC_{20} were higher in the later period.

DISCUSSION

Since we became aware, in 1985, that asthma is aggravated by secondhand smoke we have been advising all our referring doctors to urge parents who are smokers who have asthmatic children not to expose their children to their smoke.[5] Although the parents we have seen after July 1986 have continued to smoke the same total number of cigarettes as those seen before July 1986, they seem to have responded to their doctor's advice and to increased general awareness of the ill effects of secondhand smoke: they have smoked fewer cigarettes when in the house, and considerably fewer cigarettes when in the same room as their child.

Concurrent with the diminished exposure to smoke a decrease in the severity of asthma in children of smokers is shown by a significant decrease in the asthma score and a marked increase in the $FEV_1\%$, and $FEF_{25\%\text{ to }75\%}$. By entering into the model the number of cigarettes the mother and father smoked each day in the child's presence, the differences between spirometric values recorded before and after July 1986 were decreased, indicating that diminished exposure to cigarette smoke was an important factor in the improvement observed in the spirometric test values. As

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TABLE III. Correlations between numbers of cigarettes smoked per day while in the same room as the child and indicators of asthma severity

Measurement	Mother			Father		
	r	*n*	*p*	*r*	*n*	*p*
Asthma score	0.19	93	0.037	−0.040	111	0.337
FEV,%	−0.32	59	0.008	−0.344	67	0.002
FEF_{25-75}	−0.30	59	0.010	−0.234	67	0.028
Log Pc_{20}	0.11	23	0.308	−0.061	17	0.408

Number of cigarettes smoked when in the same room as the child recorded only for patients seen from June 1, 1985, through June 30, 1986, and from Jan. 1, 1989, through June 30, 1990.

a result of including in the model the regression on the number of cigarettes, the FEV_1 improved by 3%, on average, for each decrease of one cigarette the mother or father smoked when in the room with the child.

Eighty percent of the parents who were questioned about their smoking after 1988 said that they had been told by their doctor not to expose their child to smoke, and that they attempted to avoid doing so by smoking outdoors or in another room or by using maneuvers such as smoking by an open window or blowing their smoke into the fire or into the exhaust fan in the kitchen. Unfortunately, we had not previously asked this question; it was suggested to us after 1986 by increasing numbers of parents who volunteered this information on being asked how many cigarettes they smoked in the same room with the child. In children seen after 1986, therefore, it is probable that in many cases the true exposure to cigarette smoke was even less than was indicated by the number of cigarettes smoked when in the same room as the child. If parents who were questioned after 1986 had not used avoidance measures it is likely that the correlation between the number of cigarettes smoked and asthma severity would have been even stronger, and that incorporating the number of cigarettes into the model (Table IV, column 3) would have reduced even further the differences between spirometric measurements recorded before and after July 1986.

Not only was asthma less severe in smokers' children who were seen after July 1986, but also their lung function measurements were no longer lower than those found in nonsmokers' children. This large degree of improvement may be explained by smoke having caused the asthma, as well as aggravating asthma, in some smokers' children. Where smoke is the cause of asthma the wheezing should be expected to cease, or greatly improve, when exposure to smoke stops or lessens. Smoke certainly seems to be a cause of asthma in children who have had atopic dermatitis.[15] As well, Barbee et al.[16] found that the prevalence of wheezing decreased in adults who stopped smoking; the decrease was particularly marked in those who had negative skin tests to common local airborne allergens. This disproportionately large decrease of wheezing in subjects with negative skin tests suggests that they had stopped wheezing because the cause of their asthma, cigarette smoke, had ceased, but some who had positive skin tests still wheezed because of continued exposure to their specific allergen. The allergen that most commonly causes asthma in our area, and in other places is house dust mite,[17, 18] and a positive skin prick test reaction to mite was considerably more common in our asthmatic children whose mothers were nonsmokers than in those whose mothers were smokers: the proportions were 42% and 28%, respectively ($p = 0.01$). It is therefore likely that when smoke exposure decreased, those whose asthma was caused by smoke improved more than those whose asthma was caused by mites. Because mite allergy was more common in nonsmokers than in smokers' children, it is understandable that asthma severity could become comparable in the two groups, or could become even less severe in smokers' children.

Cigarette smoke from the parents appears to aggravate the children's asthma more than does cigarette smoke from other sources (Murray AB, Morrison BJ. Unpublished data), but it is nonetheless possible that secondhand smoke from other people also has an effect. The latter type of exposure is difficult to quantitate: parents seldom know how many cigarettes their children are exposed to at day-care centers, at babysitter's homes, and in public places. It is probable, however, that such exposure has progressively decreased as public awareness about the ill effects of smoke pollution has become more general, as smoking in public places has been banned, and as the prevalence of smoking in Canada has decreased. Between 1986 and 1989 the average number of cigarettes smoked per person per day has decreased from nine

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TABLE IV. Indicators of asthma severity; mean values adjusted for sex, age, and age of onset of asthma

	Column 1: neither parent smokes July 1986 before vs after	Column 2: either parent smokes July 1986 before vs after	Column 3: either parent smokes Adjusted for cigarettes* July 1986 before vs after
Asthma score	6.45 vs 6.62 (n = 418, p = 0.55)	7.48 vs 6.49 (n = 146, p = 0.047)	7.50 vs 6.48 (n = 146, p = 0.064)
FEV_1%	84.7 vs 89.9 (n = 260, p = 0.005)	79.2 vs 93.7 (n = 93, p = 0.000)	80.8 vs 92.2 (n = 93, p = 0.003)
FEF_{25-75}%	71.2 vs 77.6 (n = 260, p = 0.041)	67.3 vs 82.0 (n = 93, p = 0.009)	68.7 vs 80.65 (n = 93, p = 0.052)
Log PC_{20}	0.41 vs 0.16 (n = 71, p = 0.45)	0.18 vs 0.32 (n = 30, p = 0.78)	0.21 vs 0.30 (n = 30, p = 0.84)

*Adjusted for the number of cigarettes parents smoked when in the same room with child. Number recorded on patients seen from June 1, 1985, through June 30, 1986, and from Jan. 1, 1989, through June 30, 1990.

to seven.[16] This decrease may have accounted for some of the improvement observed in nonsmokers' children as well as in smokers' children. Not surprisingly, however, the improvement was much greater in those whose parents were smokers.

When comparing mean PC_{20} values before and after July 1986 in our population of smokers' children as a whole, significant improvement occurred in the later period for children of fathers who smoked but not those of mothers who smoked. Also, no significant correlation occurred between the number of cigarettes the mother or father smoked and the child's PC_{20}. A reanalysis of the data, including children whose bronchi did not respond significantly to 8 mg/ml histamine, produced similar results. This lack of correlation is unexpected because a significant correlation between the number of cigarettes smoked by the mother and bronchial responsiveness in the child has been reported in studies performed before 1986 by us,[1-13] and a significant difference between the bronchial responsiveness in children of mothers who smoked and those who did not has been observed by O'Connor et al.[3] and by Martinez et al.[4] A possible explanation for the lack of association in our present population is that lifelong exposure to a chemical in the parents' cigarette smoke had induced long-lasting hyperresponsiveness in some of the children's bronchi, a hyperresponsiveness that was not reversed by a comparatively recent decrease in exposure to smoke pollution. Adults with chemically induced hyperresponsiveness, and whose exposure to the chemical has ceased, often have a normal FEV_1 but a persistently abnormal PC_{20}.[20]

Because factors other than smoke may possibly have influenced our results, they should also be considered. One is that air pollution may have decreased over the study period. However, no change occurred in O_3, SO_2, and NO_2 levels monitored daily throughout the study period at 11 sites in the Greater Vancouver Regional District[21] (Bates DV, 1992, Unpublished data). Another is that exposure to airborne allergens may have decreased with time. Although this possibility cannot be ruled out, we detected no obvious difference between the two time periods in the amounts of pollens that we trapped by the gravity method, and in smokers' children the frequency and size of positive skin test reactions to mite were slightly greater in the later than in the earlier period. A third factor to be considered is the increased frequency with which corticosteroids have been given to asthmatic patients in recent years. Use of corticosteroids by children of nonsmokers increased, 8% of them used them in the earlier period and 15% took corticosteroids in the later period, and it is likely that this more frequent use of corticosteroids contributed to the improved spirometric measurements that were observed in children of nonsmokers who were seen after July 1986. In children of smokers, by contrast, a marked decrease of frequency occurred with which corticosteroids were used by those seen in the later than in the earlier period (20% vs 5%, p = .00). This significant decrease is further evidence that severity of asthma lessened in smokers' children when they were exposed to fewer cigarettes. Fourth, the pattern of use of another class of medication may also have changed, that of the beta-agonist bronchodilators. We have no data on these bronchodilators specifically, but this was the class of medication most commonly used by the patients that

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had been referred to us, and medication use is reflected in the asthma score (Appendix). When comparing the later with the earlier time period, the asthma score decreased significantly in children of smokers, but increased slightly in the children of nonsmokers, the children who made up the large majority of our subjects. Fifth, it is possible that parents underestimated the number of cigarettes to which they exposed their children each day, particularly during the later period. We do not think that untruthful reporting caused a serious bias because 7-year-old children are nowadays usually well aware of the harmful effects of smoking and are quick to correct their parents' estimate if the reported number of cigarettes is falsely low. As well, a highly significant correlation occurred between the number of cigarettes reported and the spirometric test results. Sixth, we have no objective data on the frequency of viral respiratory infections, but we did inquire about the frequency of colds. These were reported to be slightly more frequent in the later than in the earlier period in smokers' children.

There is evidence that since 1986 an increasing awareness of the harmful effects of secondhand smoke has caused parents to smoke fewer cigarettes when with their asthmatic children, and that the resulting decrease in exposure has been associated with a marked improvement in the severity of asthma of the smokers' children who have been referred to our clinic.

We thank Janice Fuller, RN, for asking the standardized questions, Mrs. Huguette Brown and Mrs. Radana Vaughan for performing the tests, and Mr. Ronnie Sizto for computer programming.

APPENDIX: Asthma score*

History	Score 0	1	2	3	4
Parent's assessment of severity	None	Mild	Moderate	Severe	
Wheezing, number of days	None	1-3	4-182	183-365	
Medication, number of days	None	1-3	4-30	31-182	183-365
Corticosteroid medication	None			Yes	
Wheezing on exertion	None	Yes			

*Numeric score indicating severity assigned to each feature in the history.

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Defective antipneumococcal polysaccharide antibody response in children with recurrent respiratory tract infections

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Background: *Recurrent pyogenic infections are known to occur in patients with an impaired response to polysaccharide antigens. We investigated the occurrence of deficient responses to pneumococcal capsular polysaccharides in patients with recurrent respiratory tract and recurrent systemic infections.*

Methods: *Forty-five patients, 1.7 to 17.1 years of age, were immunized with 23-valent pneumococcal polysaccharide vaccine. Antibody levels to seven pneumococcal serotypes (3, 4, 6A, 9N, 14, 19F, 23F) were determined by ELISA before and after immunization. In addition, patients received a booster immunization with diphtheria toxoid, tetanus toxoid, and poliomyelitis virus vaccine.*

Results: *Thirty-five patients had normal serum immunoglobulin levels. Five of these patients (14%) had low antipneumococcal preimmunization antibody levels and failed to respond to pneumococcal vaccination, whereas the response to booster immunization with protein antigens was appropriate. Three patients were younger than 3 years old, and one had a family history of IgG2 deficiency. Low IgG developed in a fifth patient during follow-up. Ten patients had a humoral immunodeficiency. Seven of these patients failed to respond to pneumococcal vaccination.*

Conclusions: *We conclude that a defective immune response to polysaccharide antigens in patients requires long-term follow-up to distinguish transient maturational delay from a persistent selective impaired response to polysaccharide antigens, which on occasion may precede the development of humoral immunodeficiency disease. (J ALLERGY CLIN IMMUNOL 1993;91:110-9.)*

Key words: Pneumococci, antipolysaccharide antibodies, respiratory tract, Fallot, immunodeficiency, cell wall polysaccharide, otitis

The development of antibodies to polysaccharides of encapsulated bacteria such as *Streptococcus pneumoniae* and *Haemophilus influenzae* type b in early life is much poorer than to proteins. For many polysaccharide antigens, adequate antibody titers are not attained until the age of 18 to 24 months or later after infection or vaccination with polysaccharide vaccines.[1-6] The key component of the host defense against encapsulated bacteria is opsonophagocytosis of the microorganism for which the presence of specific anticapsular antibodies, complement and phago-

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